[illegible] See Dec '75 Issue

Westinghouse

Medium Voltage Metal-Clad Switchgear Type DHP

Application on Symmetrical Current Rating Basis

Table 1: Application: Available Breaker Types

Identification: Circuit Breaker Type	Identification: Nominal Voltage Class, Kv Class	Identification: Nominal 3-Phase MVA Class, MVA Class	Rated Values – Voltage: Rated Maximum Voltage E, Kv rms	Rated Values – Voltage: Rated Voltage Range Factor ② K	Rated Values – Insulation Level, Rated Withstand Test Voltage: Low Frequency, Kv rms	Rated Values – Insulation Level, Rated Withstand Test Voltage: Impulse, Kv rms	Rated Values – Current: Rated Continuous Current, Amperes	Rated Values – Current: Rated Short Circuit Current (at rated Max. Kv) ② I, KA rms	Rated Interrupting Time, Cycles	Rated Permissible Tripping Delay ④ Y, Sec.	Related Required Capabilities③: Rated Max. Voltage Divided By K, E/K, Kv rms	Related Required Capabilities③ – Current Values: Maximum Sym. Interrupting Capability, K Times Rated Short-Circuit Current② KI, KA rms	Related Required Capabilities③ – Current Values: 3 Sec. Short-Time Current Carrying Capability, K Times Rated Short-Circuit Current② KI, KA rms	Related Required Capabilities③ – Current Values: Closing and Latching Capability (Momentary), 1.6 K Times Rated Short-Circuit Current, KA rms
50 DHP 75	4.16	75	4.76	1.36	19	60	1200	8.8	5	2	3.5	12	12	19
50 DHP 250		250		1.24			1200 2000	29			3.85	36	36	58
H50 DHP 250①							1200 2000							78①
50 DHP 350		350		1.19			1200 2000 3000	41			4.0	49	49	78
75 DHP 500	7.2	500	8.25	1.25	36	95	1200 2000	33	5	2	6.6	41	41	66
150 DHP 500	13.8	500	15	1.30	36	95	1200 2000	18	5	2	11.5	23	23	37
H 150 DHP 500①							1200 2000							58①
150 DHP 750		750					1200 2000	28				36	36	58
H 150 DHP 750①							1200 2000							77①

① Non-Standard Breaker with High Momentary Rating available for Special Applications.

② For 3 phase and line to line faults, the sym. interrupting capability at a Kv operating voltage

$=\frac{E}{Kv}$ (Rated Short-Circuit Current)

But not to exceed KI.
Single line to ground fault capability at a Kv operating voltage

$=1.15\frac{E}{Kv}$ (Rated Short-Circuit Current)

But not to exceed KI.
The above apply on predominately inductive or resistive 3-phase circuits with normal-frequency line to line recovery voltage equal to the operating voltage.

③ For Reclosing Service, the Sym. Interrupting Capability and other related capabilities are modified by the reclosing capability factor obtained from the following formula:

$$R\ (\%) = 100 - \frac{C}{6}\left[(n-2) + \frac{15-T_1}{15} + \frac{15-T_2}{15} + \ldots\right]$$

Where C = KA Sym. Interrupting Capability at the Operating Voltage but not less than 18
n = Total No. of Openings
T_1, T_2, etc. = Time interval in seconds except use 15 for time intervals longer than 15 sec.

Note: Reclosing Service with the standard duty cycle 0+15s+CO Does not require breaker Capabilities modified since the reclosing capability factor R = 100%

④ Tripping may be delayed beyond the rated permissible tripping delay at lower values of current in accordance with the following formula:
T (seconds) =

$$Y\left[\frac{\text{KI (K Times Rated Short-Circuit Current)}}{\text{Short-Circuit Current Through Breaker}}\right]^2$$

The aggregate tripping delay on all operations within any 30 minute period must not exceed the time obtained from the above formula.

Application Considerations

Westinghouse medium voltage metal-clad switchgear provides control and protection for generators, motors, transformers and all types of feeder circuits. In the usual application the selection of the circuit breaker for the operating voltage, to carry the load current and provide for the interruption of the available short-circuit is of primary importance. The purpose of this application data is to aid in this selection.

It should be noted that for a particular application there may be other items of technical importance that require careful consideration. Also requirements for special applications or unusual service conditions should be referred to the nearest Westinghouse Sales Office with details and a request for recommendations.

Rated Maximum Voltage

The kv operating voltage should not exceed the rated maximum voltage, E in Table 1, since this is the upper limit for operation.

Rated Continuous Current

The continuous current rating of a circuit breaker is a maximum rating. The circuit breaker rating should always be in excess of the utilization equipment rating to provide for short time overload capability.

Transformer main breakers should be rated in excess of 125% of transformer full load amperes. Always consider forced cooled rating, possible future forced cooling and 12% additional capacity for 65°C. rise rating when used.

February, 1972
New Information
E. D. C/1942/DB

Westinghouse

Induction motor and synchronous motor starting breakers should be rated in excess of 125% of motor full load amperes.

Generator breakers should be in excess of 125% of generator full load current. Other factors such as increased capacity at 1.0 power factor, reduced voltage or low ambient temperature rating may have to be considered.

Capacitor bank feeder breakers should have a rating in excess of 135% of the bank full load current. This is due to a 0 to +15% manufacturing tolerance in capacitors, KVAR due to harmonic currents and possibility of up to 10% overvoltage. Capacitor switching is generally limited to 1200 ampere breakers since larger size banks are switched in steps and other factors such as limiting transient voltages and momentary duty from switching capacitors back to back or other limitations due to the type of breaker may have to be considered.

Interrupting Capability

Table 1 lists rated short-circuit current at rated voltage for the various available circuit breaker types which is adjusted for the operating voltage to obtain the 3 phase symmetrical interrupting capability. This value is multiplied by 1.15 to obtain the single line to ground capability. Note that the 3 phase or single line to ground capabilities may not exceed KI, the maximum symmetrical interrupting capability.

Although these capabilities are expressed in sym. kilo-amperes, the circuit breaker shall be able to interrupt all values of assymmetrical as well as symmetrical short-circuit current from a system having an X/R ratio of 15 or less.

Short-Circuit Duty

To check the breaker application from an interrupting standpoint, compare the interrupting capability at the operating voltage with the short-circuit duty determined for the point of application in the power system.

Table 2 lists multiplying factors depending upon the system X/R ratio and the breaker rated interrupting time to obtain the maximum short-circuit duty. If the maximum multiplying factor for the source of short-circuit current is used, it is not necessary to calculate the system X/R ratio. If the system X/R ratio is 15 or less, the multiplying factor is 1.0.

Short-Circuit Duty=E/X amperes (Max. Mult. Factor)

A closer check of the application requires calculation of the system X/R ratio. It is sufficiently accurate (on the conservative side) to neglect the resistance component when calculating the system reactance X and neglect the reactance component when calculating the system resistance R. Use actual equipment data for important electrical devices wherever possible.

Typical data for various system components is included in Table 3 for estimating purposes.

System X/R ratio $= \frac{X_1}{R_1}$ for 3 phase faults

and $= \frac{2X_1 + X_o}{2R_1 + R_o}$ for single line to ground faults where X_1 and X_o are positive and zero sequence reactances, R_1 and R_o are positive and zero sequence resistances.

System X/R ratio so determined is used to obtain the E/X ampere multiplying factor from Table 2.

Short-Circuit Duty=E/X amperes (Mult. Factor Table 2)

Table 2: Multiplying Factor for E/X Amperes

SOURCE OF SHORT CIRCUIT	X/R Ratio Range
LOCAL	
From local syn. machines directly through transformer rated 25 to 100 MVA.	30 – 50
② **Max. Mult. Factor** 1.25 3Ø Fault; 1.43 LG Fault	
From syn. machines at breaker voltage	40 – 160
② **Max. Mult. Factor** 1.25 3Ø Fault; 1.43 LG Fault	
REMOTE	
From remote syn. machines through transformers rated 25 to 100 MVA where transformers provide 90% or more of total equivalent impedance to the point of fault.	15 – 40
② **Max. Mult. Factor** 1.25 3Ø or LG	
From remote or local syn. machines at breaker voltage through current limiting reactors where reactors contribute predominately to the reactance of the circuit.	40 – 120
② **Max. Mult. Factor** 1.43 3Ø or LG	

System X/R	Type of Circuit Breaker, DHP Rated Interrupting Time, 5 Cycle		
	Type of Fault		
Ratio	3 Ø	LG	3 Ø & LG
	Source of Short Circuit		
	Local		Remote
1	1.00	1.00	1.00
①15	1.00	1.00	1.00
20	1.00	1.02	1.05
25	1.00	1.06	1.10
30	1.04	1.10	1.13
35	1.06	1.14	1.17
40	1.08	1.16	1.22
45	1.12	1.19	1.25
50	1.13	1.22	1.27
55	1.14	1.25	1.30
60	1.16	1.26	1.32
65	1.17	1.28	1.33
70	1.19	1.29	1.35
75	1.20	1.30	1.36
80	1.21	1.31	1.37
85			1.38
90	1.22	1.32	1.39
95			1.40
100	1.23	1.33	1.41
110	1.24	1.34	1.42
120	1.24	1.35	1.43
130	1.24	1.35	1.43

① Where system X/R ratio is 15 or less, the mult. factor is 1.0.

② Not necessary to calculate the system X/R ratio when max. mult. factor is used.

Medium Voltage Metal-Clad Switchgear Type DHP

Application on Symmetrical Current Rating Basis

E/X Amperes Calculations

Short circuit calculations usually consist of simple E/X computations:

3 phase fault: $I_{3\varnothing}=\frac{E}{X}$

single line to ground fault: $I_{LG}=\frac{3E}{2X_1+X_0}$

where E is line to neutral operating voltage, and reactances are ohms, per phase, line to neutral.

Computations are simplified by selection of a common base and using the per unit system of calculations:

3 phase fault: $I_{3\varnothing}=\frac{I_B}{X}$

single line to ground fault: $I_{LG}=\frac{3I_B}{2X_1+X_0}$

Where I_B is the base current in kilo-amperes and reactances are in per-unit of the common base. Convenient per-unit system formulas:

$$I_B=\frac{\text{MVA Base}}{\sqrt{3}\text{ Kv}} \qquad \text{Base ohms}=\frac{KV^2}{MVA}$$

$$\text{per unit } X=\frac{X}{MVA}\text{ MVA base or }=\frac{X}{I}\,I_B$$

$$\text{or }=\frac{\text{X ohms}}{\text{base ohms}}\text{ or }=\frac{\text{X percent}}{100}$$

Where system is impedance grounded to limit the single line to ground fault to the 3 phase fault value or lower, only the 3 phase fault calculations are necessary.

Table 3 lists reactances quantity to be used for X for the various system components. Use actual data for important electrical devices wherever possible. Typical data is included for estimating purposes.

The E/X amperes determined are in rms symmetrical kilo-ampere.

Momentary Duty

When motor contribution exceeds 10% of the total short circuit, an additional calculation should be made to determine the momentary duty using the reactance quantities for momentary duty from Table 3.

Momentary Duty=1.6 E/X Amperes

Compare momentary duty with close and latch capability or momentary rating listed in Table 1.

Table 3: Reactance X for E/X Amperes

System Component	Reactance X Used for		Typical Values & Range on Component Base	
	Short-Circuit Duty	Momentary Duty	% Reactance	X/R Ratio
2 Pole Turbo Generator	X	X	9 / 7 – 14	80 / 40 – 120
4-Pole Turbo Generator	X	X	14 / 12 – 17	80 / 40 – 120
Hydro Gen. with Damper Wdgs. and Syn. Condensers	X	X	20 / 13 – 32	30 / 10 – 60
Hydro. Gen. without Damper Windings	.75 X	1.0 X	30 / 20 – 50	30 / 10 – 60
All Synchronous Motors	1.5 X	1.0 X	24 / 13 – 35	30 / 10 – 60
Ind. Motors above 1000 HP, 1800 RPM and above 250 HP, 3600 RPM	1.5 X	1.0 X	25 / 15 – 25	30 / 15 – 40
All Other Induction Motors 50 HP and Above	3.0 X	1.2 X	25 / 15 – 25	15 / 5 – 20
Ind. Motors Below 50 HP and all Single Phase Motors	Neglect	Neglect	......	......
Distribution System from Remote Transformers	X	X	as Specified or Calculated	15 / 5 – 15
Current Limiting Reactors	X	X	as Specified or Calculated	80 / 40 – 120
Transformers OA to 10 MVA, 69 KV	X	X	5.5 / 5 – 7	10 / 6 – 12
OA to 10 MVA, above 69 KV	X	X	7.5 / 7 – 11	12 / 8 – 15
FOA 12 to 30 MVA	X	X	10 / 8 – 24	20 / 10 – 30
FOA 40 to 100 MVA	X	X	15 / 8 – 35	30 / 20 – 40

For machines use subtransient reactance Xd" for X.

For other system components use positive sequence reactance X_1 for X.

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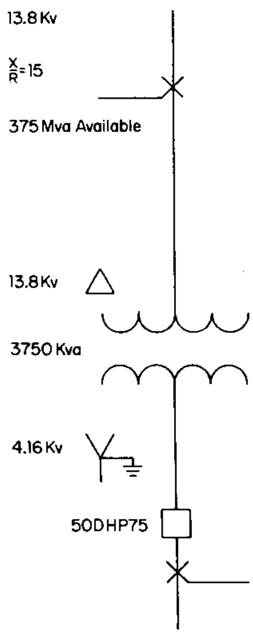
Example 1 – Fault Calculations

Type Breaker	E Max.	3 ⌀ Sym. Interrupting Capability @ E. Max.	Max. KI	@ 4.16 Kv Oper. Voltage	Close & Latch or Momentary
50DHP75	4.76	8.8 KA	12 KA	$\frac{4.76}{4.16}$ (8.8) = 10.1 KA ②	19 KA ①
		LG Sym. Interrupting Capability			
			12 KA	1.15 (10.1) = 11.6 KA ③	

Note: Interrupting capabilities ② and ③ at operating voltage do not exceed max. sym. interrupting capability KI.

Check capabilities ① ② and ③ on the following utility system where motor contribution to short circuit is small and may be safely ignored.



On 13.8 Kv System, 3.75 Mva Base

$Z = \frac{3.75\,Mva}{375\,Mva} = .01$ pu or 1%

$Z^2 = X^2 + R^2 = R^2\left(\frac{X^2}{R^2} + 1\right)$

$R = \frac{Z}{\sqrt{\frac{X^2}{R^2}+1}} = \frac{1}{\sqrt{226}} = \frac{1}{15.03} = .066\%$

$X = \frac{X}{R}(R) = 15(.066) = .99\%$

Transformer Standard 5.5% Impedance has a ±7.5% Manufacturing Tolerance

Transformer Z = 5.50 Standard Impedance − .41 (−7.5% Tolerance) = 5.09%

From transformer losses R is calculated

31,000 Watts Full Load
−6,800 Watts No Load
24,200 Watts Load Losses

$R = \frac{24.2\,KW}{3750\,KVA} = .0065$ pu or .65%

Transformer $X = \sqrt{Z^2 - R^2} = \sqrt{(5.09)^2 - (.65)^2} = \sqrt{25.91 - .42} = \sqrt{25.48}$
$X = 5.05\%$

	X	R	X/R
13.8 Kv System	.99%	.066%	15
Transformer	5.05	.65	8
System Total	6.04%	.716%	9
or	.0604 pu	.00716 pu	

For 3 Phase Fault

$I_{3\varnothing} = \frac{E}{X}$ where X is ohms per phase and E is line to neutral voltage

or $I_{3\varnothing} = \frac{I_B}{X}$ where X is per unit reactance and I_B is base current.

Base current $I_B = \frac{3.75\,MVA}{\sqrt{3}\;4.16\,KV} = .52$ KA

$I_{3\varnothing} = \frac{I_B}{X} = \frac{.52}{.0604} = 8.6$ KA Sym.

System $\frac{X}{R} = 9$ (is less than 15) would use 1.0 mult. factor for short-circuit duty, therefore, short-circuit duty is 8.6 KA sym. for 3⌀ fault ② and momentary duty is 8.6 x 1.6 = 13.7 KA ①

For Line to Ground Fault

$I_{LG} = \frac{3E}{2X_1 + X_0}$ or $= \frac{3I_B}{2X_1 + X_0}$

For this system, X_0 is the zero sequence reactance of the transformer which is equal to the transformer positive sequence reactance and X_1 is the positive sequence reactance of the system.

Therefore,

$I_{LG} = \frac{3(.52)}{2(.0604) + .0505} = 9.1$ KA Sym.

Using 1.0 mult. factor, short-circuit duty = 9.1 KA Sym. LG ③

The 50DHP75 breaker capabilities exceed the duty requirements and may be applied.

With this application, short cuts could have been taken for a quicker check of the application. If we assume unlimited short circuit available at 13.8 KV and that Trans. Z = X

Then $I_{3\varnothing} = I_{LG} = \frac{I_B}{X} = \frac{.52}{.055} = 9.5$ KA Sym.

X/R ratio 15 or less mult. factor is 1.0 for short-circuit duty

The short-circuit duty is then 9.5 KA Sym. ② ③ and momentary duty is 9.5 x 1.6 KA = 15.2 KA ①

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Example 2 – Fault Calculations
All calculations on per unit basis, 7.5 MVA Base

Base Current $I_B = \frac{7.5\ MVA}{\sqrt{3}\ 6.9\ KV} = .628\ KA$

	X	R	X/R
13.8 Kv System $X = \frac{.628}{21}\frac{(6.9)}{13.8} = .015$	.015	.001	15
Transformer	.055	.0055	10
Total Source Transf.	.070 pu	.0065 pu	11

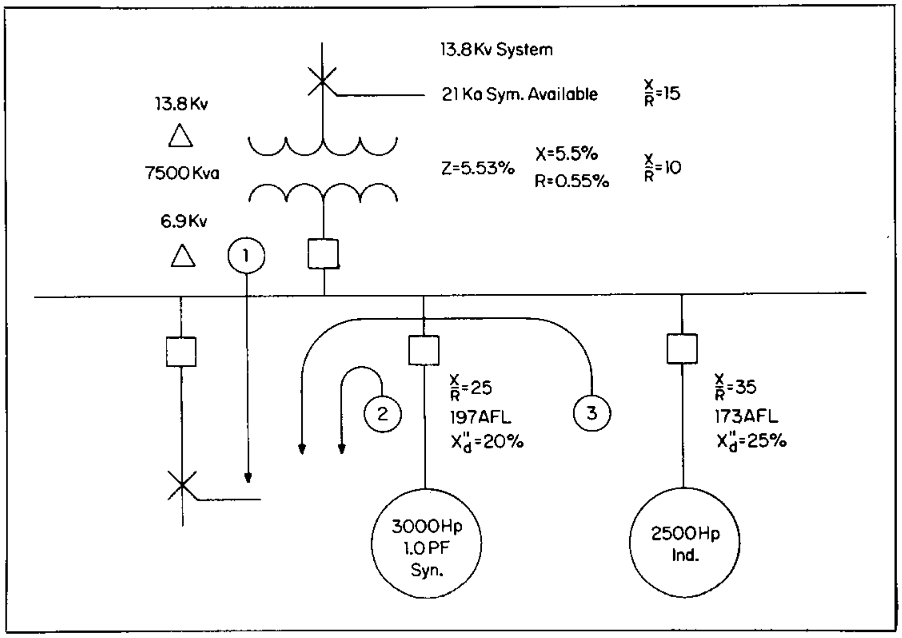
3000 HP Syn. motor

$X = .20\ \frac{(.628)}{.197} = .638$ pu at 7.5 MVA base

2500 HP Ind. Motor

$X = .25\ \frac{(.628)}{(.173)} = .908$ pu at 7.5 MVA base

$I_{3\varnothing} = \frac{E}{X}$ or $= \frac{I_B}{X}$ where X on per unit basis



Source of Short Circuit Current	Interrupting E/X Amperes	Momentary E/X Amperes	X/R	$\frac{X(1)}{R(X)} = \frac{1}{R}$
① Source. Transf.	$\frac{.628}{.070} = 8.971$	$\frac{.628}{.070} = 8.971$	11	$\frac{11}{.070} = 157$
② 3000 HP Syn. Motor	$\frac{.628}{(1.5).638} = .656$	$\frac{.628}{.638} = .984$	25	$\frac{25}{.638} = 39$
③ 2500 HP Ind. Motor	$\frac{.628}{(1.5).908} = .461$	$\frac{.628}{.908} = .691$	35	$\frac{35}{.908} = 39$
Total $X = \frac{I_B}{I_{3F}} = \frac{.628}{10.1} = .062$	$I_{3F} =$ 10.088 or 10.1 KA	10.647 x1.6 17.0 KA Momentary Duty		Total 1/R = 235

System $\frac{X}{R} = .062\ (235) = 14.5$ is Mult. Factor 1.0 from Table 3.

Short circuit duty = 10.1 KA

Type Breaker	E Max.	3Ø Sym. Interrupting Capability @ E Max.	Max. KI	@ 6.9 Kv Oper. Voltage	Close & Latch or Momentary
750DHP500	8.25	33 KA	41 KA	$\frac{8.25}{6.9}\ (33) = 39.5$ KA	66 KA
150DHP500	15	18 KA	23 KA	$\frac{15\ (18)}{6.9} = (39.1) = 23$ KA (But not to exceed KI)	37 KA

Either breaker could be properly applied, but price will make the type 150DHP500 the more economical selection.

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Example 3 – Fault Calculations
Check breaker application on generator bus where

Each generator is 7.5 MVA, 4.16 KV 1040 amperes full load, $I_B = 1.04$ KA

Sub transient reactance Xd''=11% or, X=.11 pu

Gen $\frac{X}{R}$ ratio is 30

$\frac{1}{X_s} = \frac{1}{X} + \frac{1}{X} + \frac{1}{X} = \frac{3}{X}$ and $\frac{1}{R_s} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R}$

or $X_s = \frac{X}{3}$ and $R_s = \frac{R}{3}$ Therefore, System $\frac{X_s}{R_s} = \frac{X}{R} = \text{Gen } \frac{X}{R} = 30$

Since generator neutral grounding reactors are used to limit the I_{LG} to $I_{3\varnothing}$ or below, we need only check the $I_{3\varnothing}$ short-circuit duty.

$I_{3\varnothing} = \frac{I_B}{X} + \frac{I_B}{X} + \frac{I_B}{X} = \frac{3I_B}{X} = \frac{3(1.04)}{.11} = 28.4$ KA Sym. E/X amperes

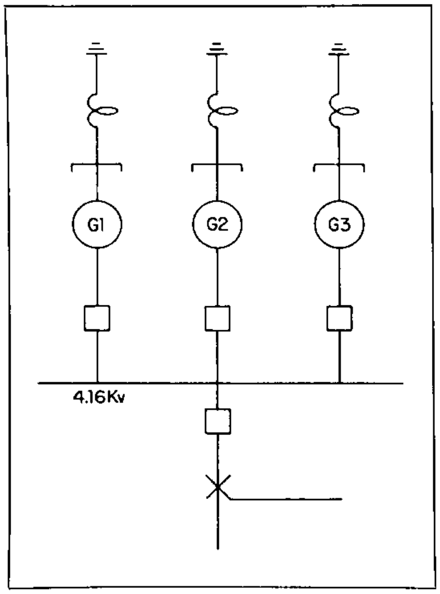
Table 3 System $\frac{X}{R}$ or 30 is Mult. factor 1.04

Short-circuit duty is 28.4 (1.04)=29.5 KA Sym.

Type Breaker	E Max.	3∅ Sym. Interrupting Capability @ E Max.	Max. KI	@ 4.16 Kv Oper. Voltage
50DHP250	4.76	29 KA	36 KA	$\frac{4.76}{4.16}(29) = 33.2$ KA
50DHP350	4.76	41 KA	49 KA	$\frac{4.76}{4.16}(41) = 46.9$ KA

The 50DHP250 breaker could be applied. However, the 50DHP350 breaker would permit addition of a future duplicate generator.

Future Short-Circuit Duty $= \frac{4(1.04)}{.11}(1.04) = 39.3$ KA Sym.



Medium Voltage Metal-Clad Switchgear Type DHP

Application on Symmetrical Current Rating Basis

Table 4: Application Quick Check Table

For application of circuit breakers in a radial system supplied from a single source transformer. Short-circuit duty was determined using E/X amperes and 1.0 multiplying factor for X/R ratio of 15 or less and 1.25 multiplying factor for X/R ratios greater than 15.

<table>
<tr><th colspan="2">Source Transformer MVA Rating</th><th colspan="5">Kv Operating Voltage</th></tr>
<tr><th colspan="2">Motor Load</th><th rowspan="2">2.4</th><th rowspan="2">4.16</th><th rowspan="2">6.6</th><th rowspan="2">12</th><th rowspan="2">13.8</th></tr>
<tr><th>100%</th><th>0%</th></tr>
<tr><td>1
1.5
2</td><td>1.5
2
2.5</td><td>50 DHP 75
12 KA</td><td rowspan="2">50 DHP 75
10.1 KA</td><td rowspan="4">150 DHP 500
23 KA</td><td rowspan="7">150 DHP 500
22.5 KA</td><td rowspan="7">150 DHP 500
19.6 KA</td></tr>
<tr><td>2.5
3</td><td>3
3.75</td><td rowspan="2">50 DHP 250
36 KA</td></tr>
<tr><td>3.75
5</td><td>5
7.5</td><td rowspan="2">50 DHP 250
33.2 KA</td></tr>
<tr><td>7.5
10①</td><td>10
10</td><td>50 DHP 350
49 KA</td></tr>
<tr><td>10</td><td>12①</td><td rowspan="2"></td><td rowspan="2">50 DHP 350
46.9 KA</td><td rowspan="4">75 DHP 500
41.3 KA</td></tr>
<tr><td>12</td><td>15</td></tr>
<tr><td>15</td><td>20</td><td colspan="2" rowspan="3">Breaker Type
and
Sym. Interrupting Capacity
at the Operating Voltage</td></tr>
<tr><td>20①</td><td>20</td><td rowspan="2">150 DHP 750
35 KA</td><td rowspan="2">150 DHP 750
30.4 KA</td></tr>
<tr><td></td><td>25
30</td><td></td></tr>
</table>

① Transformer Impedance 6.5% or more, all other Transformer Impedances are 5.5% or more.